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Preparing for and Observing the 2017 Total Solar Eclipse

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Abstract. I discuss ongoing plans and discussions for EPO and scientific observing of the 21 August 2017 total solar eclipse. I discuss aspects of EPO based on my experiences at the 60 solar eclipses I have seen. I share cloud statistics along the eclipse path compiled by Jay Anderson, the foremost eclipse meteorologist. I show some sample observations of composite imagery, of spectra, and of terrestrial temperature changes based on observations of recent eclipses, including 2012 from Australia and 2013 from Gabon. Links to various mapping sites of totality, partial phases, and other eclipse-related information, including that provided by Michael Zeiler, Fred Espenak (retired from NASA) and Xavier Jubier can be found on the website I run for the International Astronomical Union's Working Group on Eclipses at `http://www.eclipses.info`.

1. Introduction

The 2017 total solar eclipse will be the first such eclipse to cross the whole continental United States since the 1918 total solar eclipse that saw many professional expeditions, including that to Washington state by the US Naval Observatory that brought along the artist Howard Russell Butler (Pasachoff & Olson 2014; 2015). The many advances in the 99 year interval include the transfer of imaging from film to electronics, with a speed advantage of about 100-fold, and the ability to composite many images in computers, overcoming the problem of the wide dynamic range of the solar corona, which diminishes by about 1000 in brightness over a bit more than 1 solar radius outside the solar limb. The many millions and, we hope, tens of millions of Americans and visitors who will be within the 60-mile-wide path of totality will include myriads who will be using iPhones or other simple electronic cameras in addition to the imaging equipment that professionals will carry. Whether it is feasible to make a "Megamovie" (Hudson et al. 2011) from amateur images taken along the path of totality from Oregon to South Carolina will depend both on the ability to composite such a wide variety of image scales and quality, in addition, of course, to the cloudiness at the time of totality. Observations of temperature and other atmospheric changes from the eclipse darkening will also be carried out (Peñaloza-Murillo & Pasachoff 2015).

Solar astronomers from around the world will join American astronomers in carrying out scientific observations from within the path of totality (Pasachoff 2009a,b; Habbal et al. 2013). Workshops and other meetings integrating amateurs and professionals for eclipse planning have already been held, including those in College Park, Maryland (2012) and Boulder, Colorado (2013), at the Astronomical Society of the Pacific's 2014 session, and in Columbia, Missouri, site of the largest university within the path, two weeks afterwards.

2. Science Plans

Among the plans of professional astronomers is detailed imaging of the corona. The Czech computer-scientist Miloslav Druckmüller, in particular, has assembled composite images from a variety of sources, including my own (Fig. 1). In the 2013 imaging from Gabon, in west Africa, two coronal mass ejections and one erupting prominence are all visible. Their motions can be compared (Pasachoff et al. 2015) with similarly processed images taken by other scientists from other points along the path, with time intervals extending to almost an hour, giving results in the hundreds of kilometers/second. Astronomers will also take spectra, measuring coronal temperature.

Figure 1. A composite image by Miloslav Druckmüller of several dozen images taken by Jay Pasachoff, Allen Davis (my Williams College thesis student, now a Yale graduate student), and Slovakian astronomer Vojtech Rušin from Gabon. A wide variety of exposure times and apertures were used for the individual images, and a full set of dark frames and bias frames were also taken, as is commonly done to provide calibration of the images in astronomical imaging.

Observations over a whole 11-year solar activity cycle (best manifested as the sunspot cycle) shows in the shape of the corona. The 2013 corona showed streamers all around in this two-dimensional projection of the three-dimensional spiky corona. The latest sunspot cycle peaked in 2014 (a southern-hemisphere peak following by some months a northern-hemisphere peak; Fig. 2), and the 2017 corona should be much closer to solar minimum and show extended equatorial streamers and coronal plumes at the poles. These features are all controlled by the solar magnetic field.

Of course, we also now have NASA and European Space Agency (ESA) satellites in space, as well as Russian ones, to study the sun. But none of them can observe the low-to-mid solar corona that we study best at eclipses. Indeed, the Naval Research Laboratory aboard the European Space Agency's Solar and Heliospheric Observatory are now 20 years old and no obvious successor is planned. ESA/Royal Observatory of Belgium's planned pair of spacecraft, with one being an occulter at a considerable distance from the camera, is under consideration for the end of this decade (Daniel Seaton, private communication 2015).

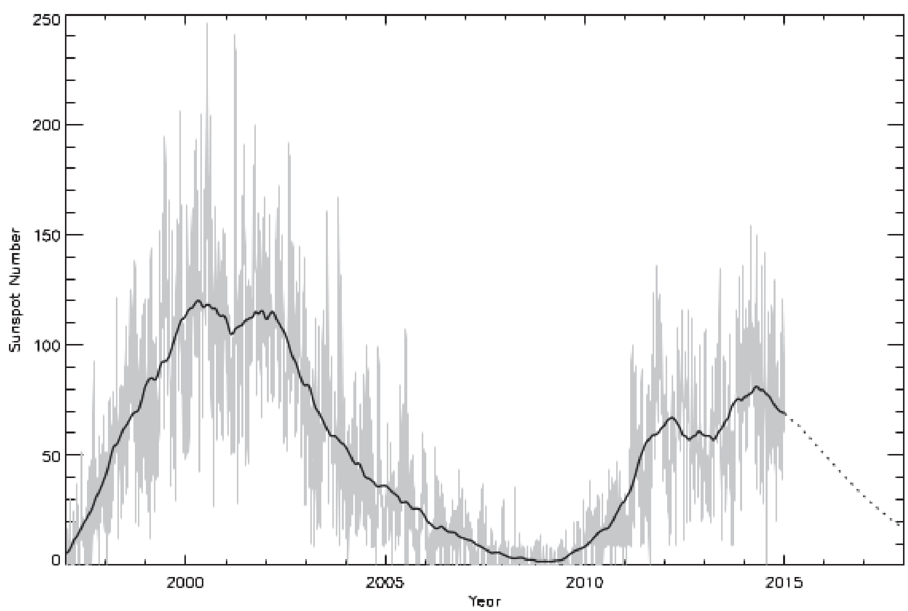

Figure 2. The most recent sunspot cycle (see also `http://sidc.oma.be/silso`). The gray band of upward and downward excursions marks daily sunspot numbers; the solid line marks the smoothed monthly average. A dashed line shows the predicted number of sunspots, which should continue declining into 2017 (Royal Observatory of Belgium/SILSO Sunspot Index and Long-term Solar Observations courtesy of Daniel B. Seaton).

3. Eclipse Mapping

Detailed maps of eclipse paths are all linked from the website I run for the Working Group on Solar Eclipses of the International Astronomical Union (IAU). The major providers of general eclipse maps are now Michael Zeiler[1] (Fig. 3), Xavier Jubier,[2]

[1] `http://eclipse-maps.com` and `http://GreatAmericanEclipse.com` specifically for 2017.

[2] `http://xjubier.free.fr/en/site_pages/SolarEclipsesGoogleMaps.html`

whose maps are scalable and on which clicking on a location brings up an information box), and Fred Espenak.[3] All these websites are easily available through my IAU website at `http://eclipses.info`.

Espenak has also released a *1000-Year Canon of Solar Eclipses, 1501–2500*,[4] which sets the travel schedule for the next years or decades for hundreds of people, including not only the eclipse astronomers and the dedicated eclipse amateur astronomers, but also the increasing number of ecotourists who have discovered how beautiful and fascinating eclipses are.

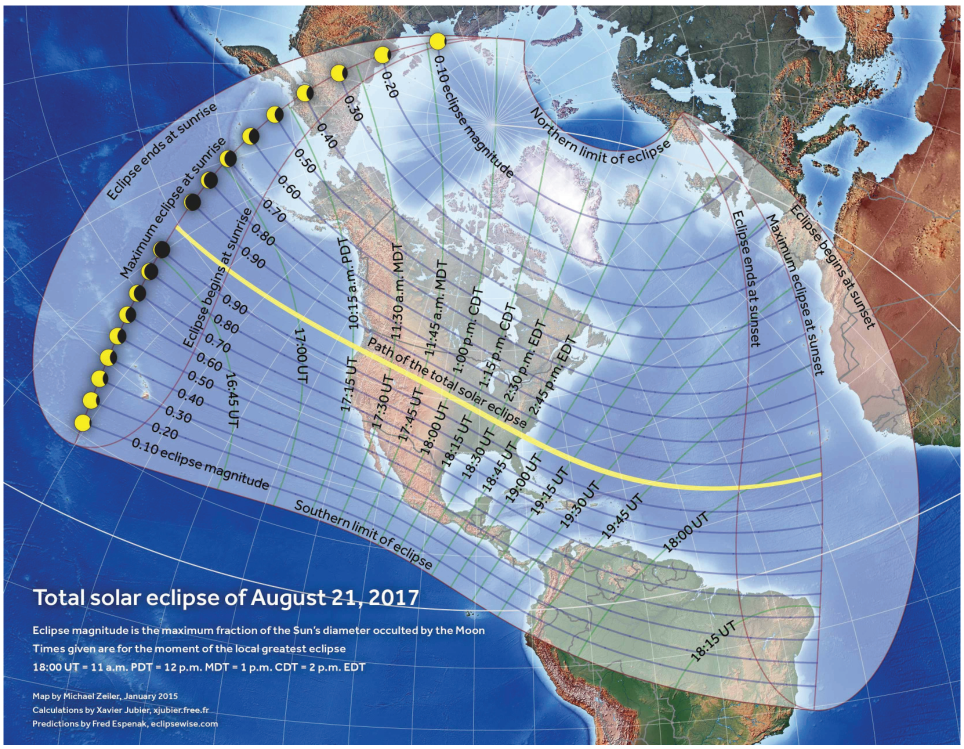

Figure 3. Michael Zeiler's map of the path of totality and of the appearance of partial eclipses across the continental United States. Hawaii has about a 38% partial eclipse magnitude (fractional diameter) at sunrise. Map by Michael Zeiler, `GreatAmericanEclipse.com`, based on calculations by Xavier Jubier `xjubier.free.fr`, which are based on predictions by Fred Espenak `eclipsewise.com`

4. Eclipse Weather

Though the darkening sky of a total eclipse can be dramatic, as was testified to at the 1999 total solar eclipse as viewed from cloudy locations in England and even in

[3]Retired from NASA, so the information formerly on the "NASA Eclipse site" is now available at `http://EclipseWise.com`

[4]`http://eclipsewise.com/pubs/ap001.html`

the Metropolitan Opera's production of the Russian opera *Prince Igor* in New York (Pasachoff & Pasachoff 2014), we would all clearly prefer to observe the 2017 total solar eclipse under clear skies. The Canadian meteorologist Jay Anderson has a detailed webpage that shows cloudiness statistics from 25 years of satellite observations[5] and detailed descriptions of causes of cloudiness and chances of clear weather along the eclipse paths.[6]

Anderson's cloudiness statistics for 2017 (Fig. 4) clearly show that the northwestern United States is favored compared with the midwest and especially compared with the southeast. The American Astronomical Society will have its High Energy Astronomy Division and its Solar Physics Division meetings in Jackson Hole, Wyoming. Even better, in terms of cloudiness statistics, is mid- and eastern Oregon (Fig. 5). Professional astronomers may well be pinned to specific locations days in advance by their need to set up and align tracking equipment, since exposures longer than, perhaps, a half second would blur the corona's image. But ordinary tourists may be free to roam on Interstates or on other roads, trying to find better weather or holes in the clouds. However, the eclipse cooling the Earth's atmosphere itself causes clouds to form or clouds to disperse, so such roaming is not guaranteed to improve viewing results compared with staying put, as history has shown in many cases.

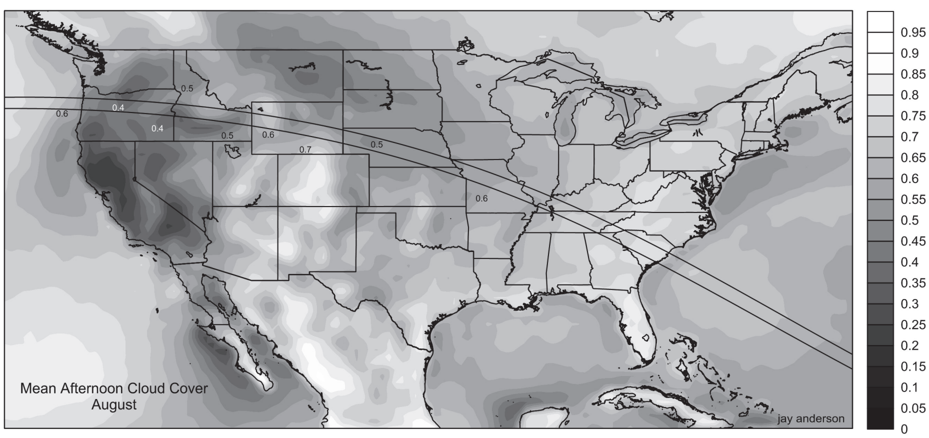

Figure 4. Meteorologist Jay Anderson's map of mean cloudiness, showing Oregon and Idaho with less than 4 tenths cloudiness (darker gray), Wyoming through Iowa showing yellow tones of 5 to 6 tenths cloudiness (gray), and South Carolina showing greater than 8 tenths cloudiness (light gray). Courtesy of Jay Anderson `http://eclipser.ca` (Data: CIMSS/NOAA/UW-Madison).

5. Recommendations and Conclusions

Eclipses provide science and spectacle (Golub & Pasachoff 2014). Of course, the most important recommendation is to travel into the path of totality. Even though the whole

[5] `http://eclipser.ca`

[6] See also Anderson, Pasachoff, & Day's *The Peterson Field Guide to Weather* to be published in 2016.

continental United States will have greater than about 60% of the solar diameter covered by the moon, the everyday sun is about a million times brighter than the corona, which is about the same brightness as the full moon (the full moon is, therefore, useful for testing exposures for cameras). So even if 99% of the everyday sun is hidden, the remaining 1% is still about 10,000 times brighter than the corona, making the sky blue and the corona invisible. We must therefore stress how important it is to travel into the zone of totality.

We must emphasize safe watching of the partial phases—and that it is totally safe to watch totality. We must stress the exciting nature of totality (and the diamond rings) for students to see, and fight the expected tendency of school boards and ophthalmologists groups to recommend that students stay inside and watch totality on TV, which would take all the excitement out of the event. The 2017 total solar eclipse is a great opportunity for student inspiration and public outreach, and we must seize it.

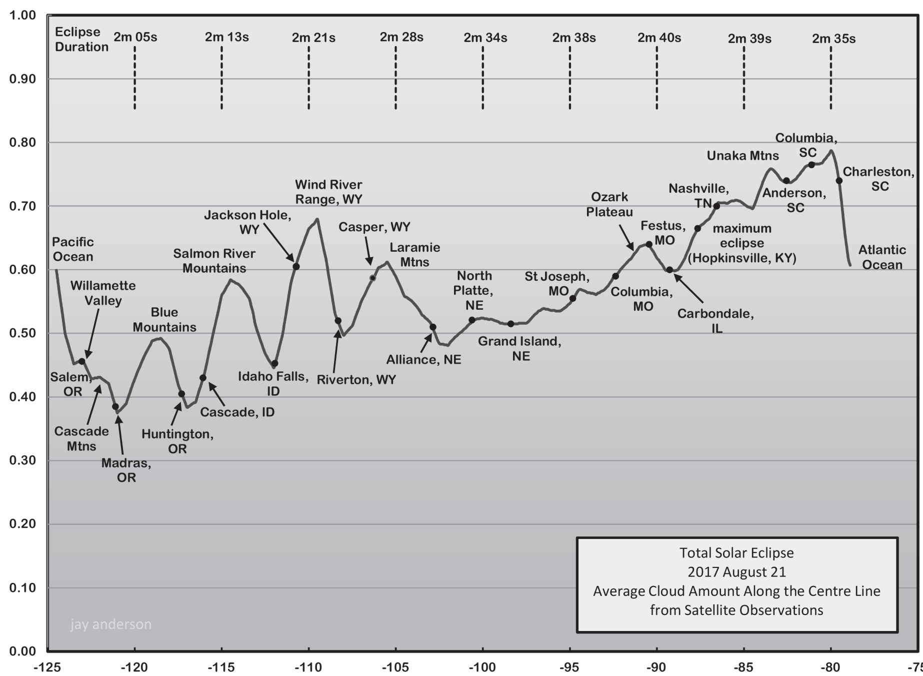

Figure 5. Anderson's graph of average cloudiness along the centerline, but for the US afternoon in all cases because of availability of data, even though the eclipse is in the morning in the western states. Courtesy of Jay Anderson `http://eclipser.ca` (Source: Patmos-X: CIMMS/SSEC).

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References

Espenak, F. 2014, 1000-Year Canon of Solar Eclipses, 1501-2500 (Astropixels Publishing, `http://eclipsewise.com/pubs/ap001.html`)

Golub, L. & Pasachoff, J. M. 2014, Nearest Star: The Surprising Science of Our Sun, 2nd ed. (Cambridge University Press)

Habbal, S. R., Morgan, H. Druckmuller, M., Ding, A., Cooper, J. F., Daw, A. & Sittler, E. C. 2013, "Probing the Fundamental Physics of the Solar Corona with Lunar Solar Occultation Observations," Solar Phys, 285, 9

Hudson, H. S., McIntosh, S. W., Habbal, S. R., Pasachoff, J. M., & Peticolas, L. 2011, "The U.S. Eclipse Megamovie in 2017: a white paper on a unique outreach event," arXiv1108.3486, `http://www.eclipse2017.org/2017/photo/eclipsemegamovie.pdf`

Pasachoff, J. M. 2009, "Solar Eclipses as an Astrophysical Laboratory," Nature, 459, 789

Pasachoff, J. M. 2009, "Scientific Observations at Total Solar Eclipses," Research in Astronomy and Astrophysics, 9, 613, `http://www.raa-journal.org/raa/index.php/raa/article/view/182`

Pasachoff, J. M., Rušin, V., Saniga, M., Babcock, B. A., Lu, M., Davis, A. B., Dantowitz, R., Gaintatzis, P., Voulgaris, A., Seaton, D. B., & Shiota, K. 2015, "Structure and Dynamics of the 13/14 November 2012 White-Light Corona," Astrophysical Journal, submitted, `http://arxiv.org/abs/1412.1155`

Pasachoff, J. M. & Olson, R. J. M. 2014, "Art of the Eclipse," Nature, 506, 314

Pasachoff, J. M. & Olson, R. J. M. 2015, "The 1918 Eclipse Mural Series by Howard Russell Butler for the American Museum of Natural History and the Hayden Planetarium," Proceedings of the Eighth meeting on the Inspiration of Astronomical Phenomena, INSAP8 `http://insap.org`, ed. Brian Abbott

Pasachoff, J. M. & Pasachoff, N. 2014, "Eclipse of power: Jay M. Pasachoff and Naomi Pasachoff take in Alexander Borodin's eclipse-inspired opera about Prince Igor," Nature, 506, 432

Peñaloza-Murillo, M. A. & Pasachoff, J. M. 2015, "Air-cooling mathematical analysis as inferred from the air temperature observation during the 1st total occultation of the Sun of the 21st century in June 21, 2001, at Lusaka, Zambia," Journal of Atmospheric and Solar-Terrestrial Physics, in press